FIG. 1

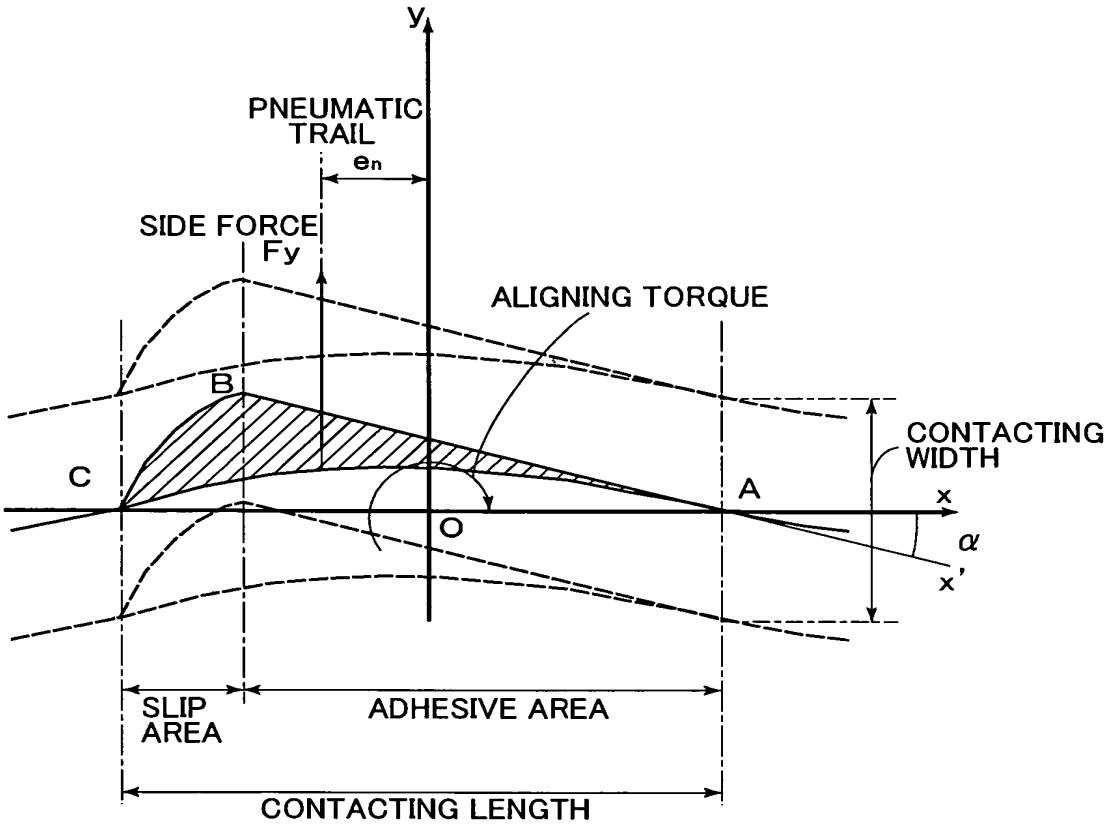

y
PNEUMATIC TRAIL
en
SIDE FORCE
Fy
ALIGNING TORQUE
B
C
A
x
O
α
x'
CONTACTING WIDTH
SLIP AREA
ADHESIVE AREA
CONTACTING LENGTH

FIG. 2

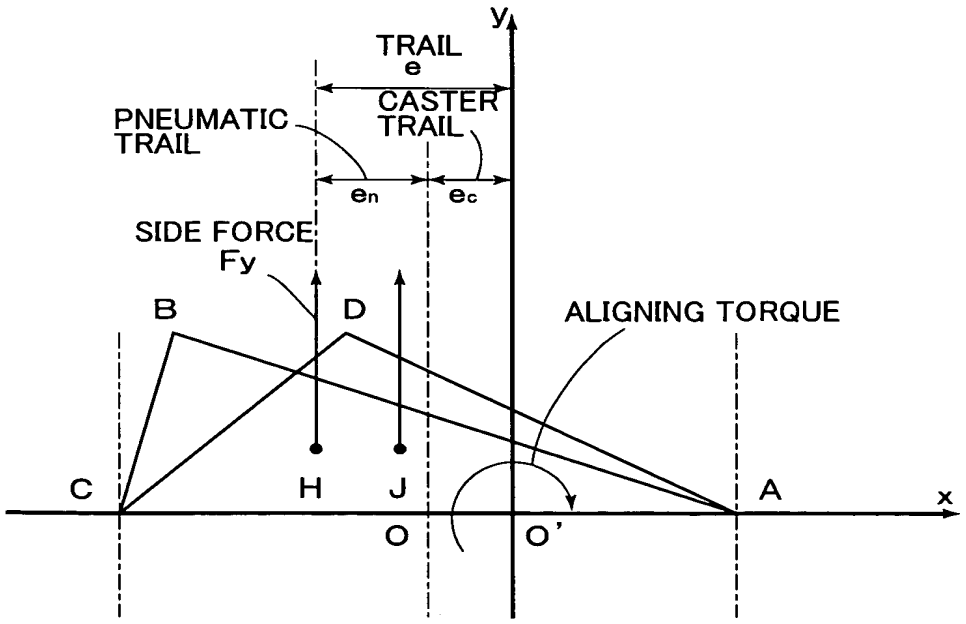

y
TRAIL
e
CASTER TRAIL
PNEUMATIC TRAIL
en
ec
SIDE FORCE
Fy
B
D
ALIGNING TORQUE
C
H
J
A
x
O
O'

FIG. 3

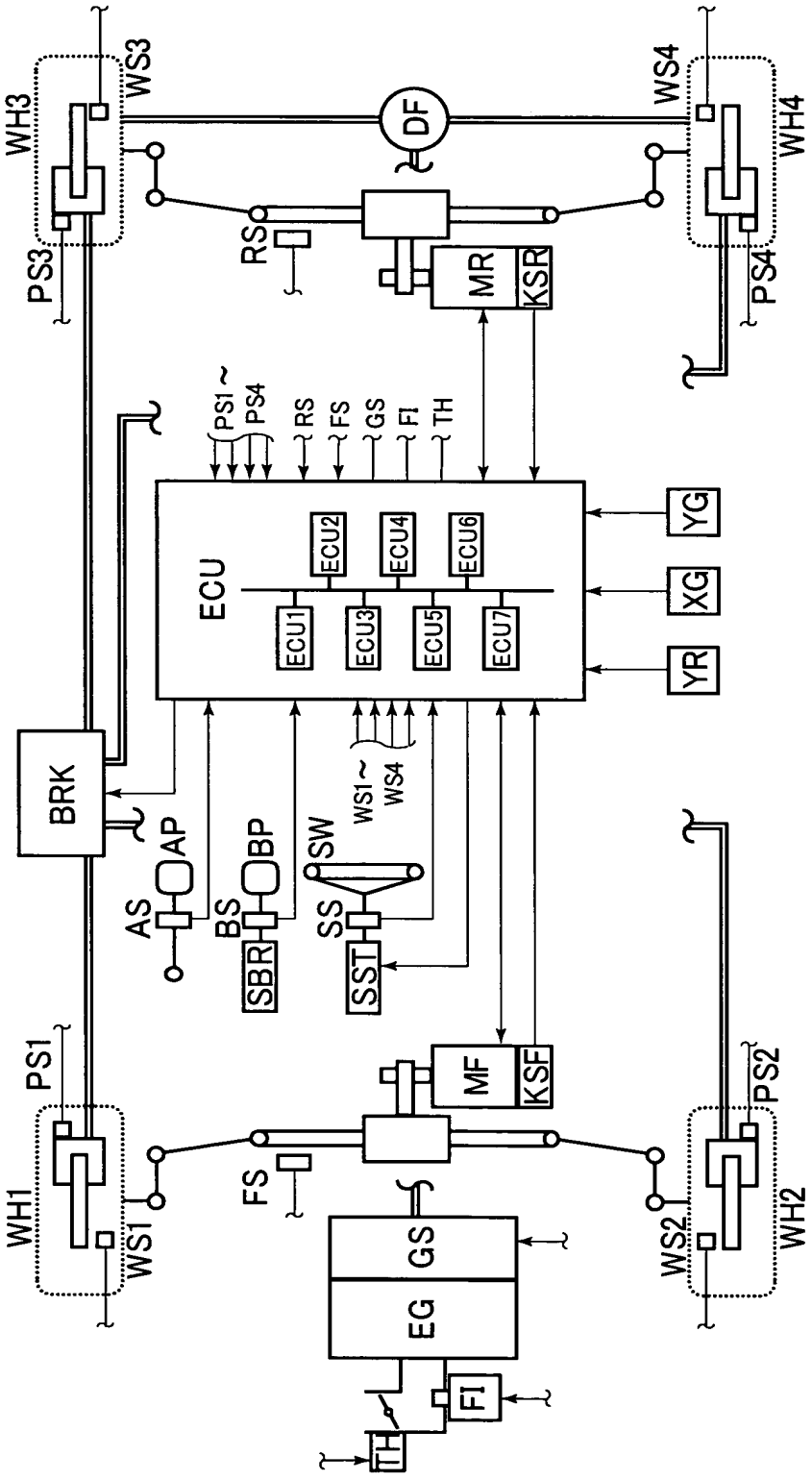

WH3
WS3
WS4
WH4
DF
RS
MR
KSR
PS3
PS4
PS1 ~ PS4
RS
FS
GS
FI
TH
ECU
ECU2
ECU4
ECU6
ECU1
ECU3
ECU5
ECU7
YG
XG
YR
BRK
WS1 ~ WS4
AP
BP
SW
AS
BS
SS
SBR
SST
PS1
MF
KSF
PS2
FS
WH1
WS1
WS2
WH2
GS
EG
FI
TH

FIG. 4

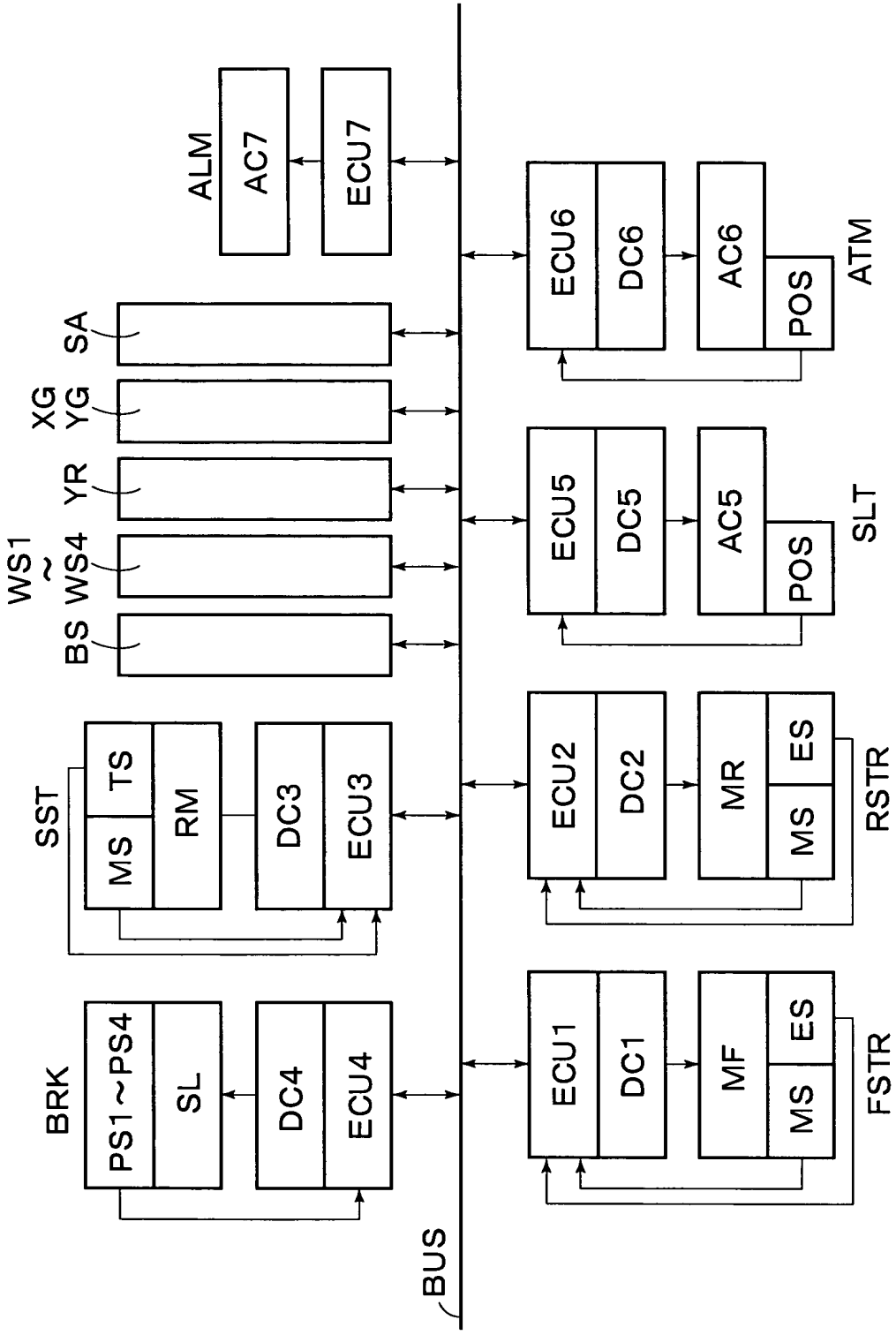

BUS
BRK
PS1~PS4
SL
DC4
ECU4
SST
MS
TS
RM
DC3
ECU3
BS
WS1
~
WS4
YR
XG
YG
SA
ALM
AC7
ECU7
ECU1
DC1
MF
MS
ES
FSTR
ECU2
DC2
MR
MS
ES
RSTR
ECU5
DC5
AC5
POS
SLT
ECU6
DC6
AC6
POS
ATM

FIG. 5

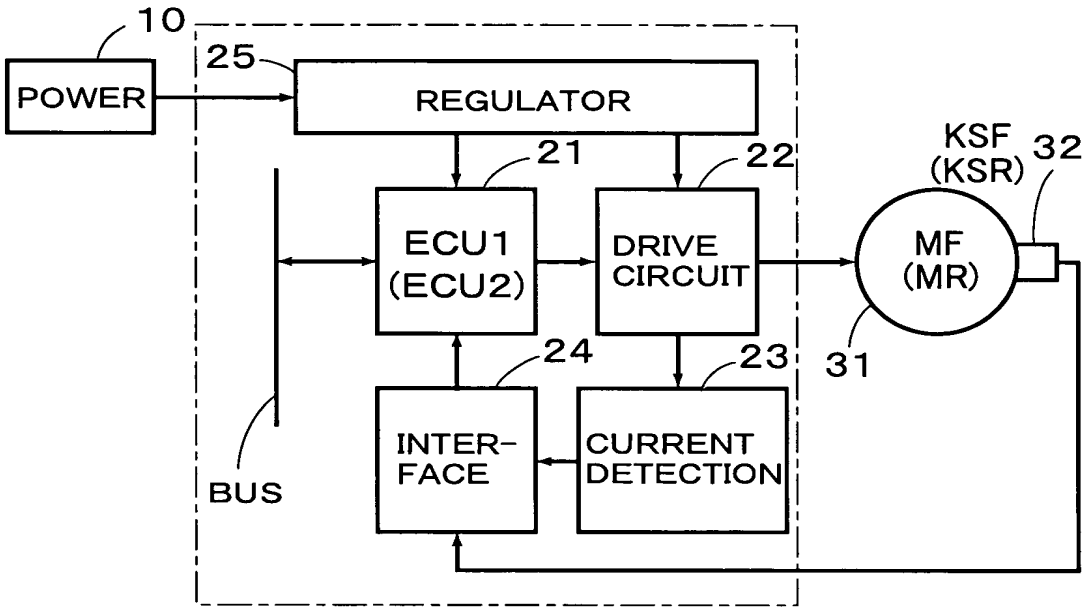

10
25
POWER
REGULATOR
21
22
KSF
(KSR)
32
ECU1
(ECU2)
DRIVE
CIRCUIT
MF
(MR)
31
24
23
INTER-
FACE
CURRENT
DETECTION
BUS

FIG. 6

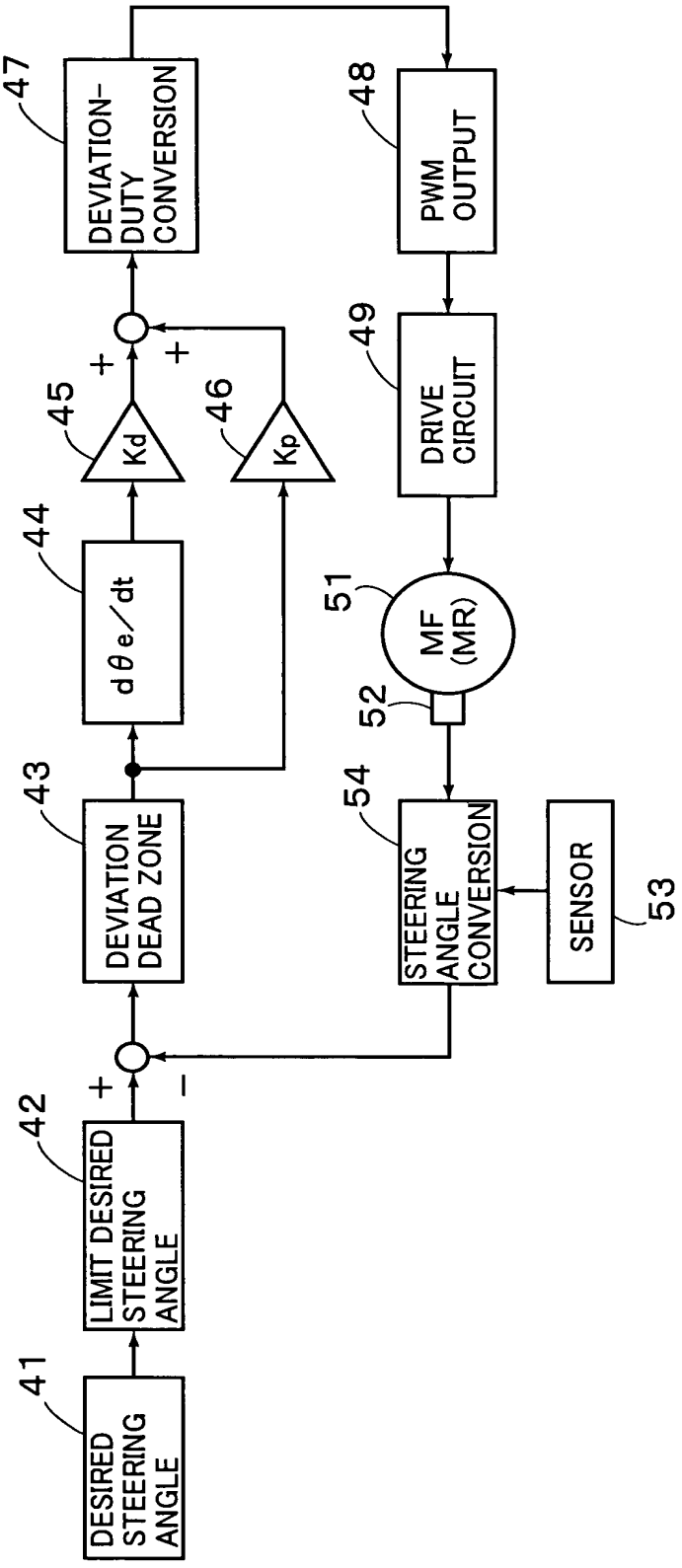

41
DESIRED STEERING ANGLE
42
LIMIT DESIRED STEERING ANGLE
43
DEVIATION DEAD ZONE
44
dθe/dt
45
Kd
46
Kp
47
DEVIATION-DUTY CONVERSION
48
PWM OUTPUT
49
DRIVE CIRCUIT
51
MF (MR)
52
54
STEERING ANGLE CONVERSION
SENSOR
53
+
+
+
−

FIG. 7

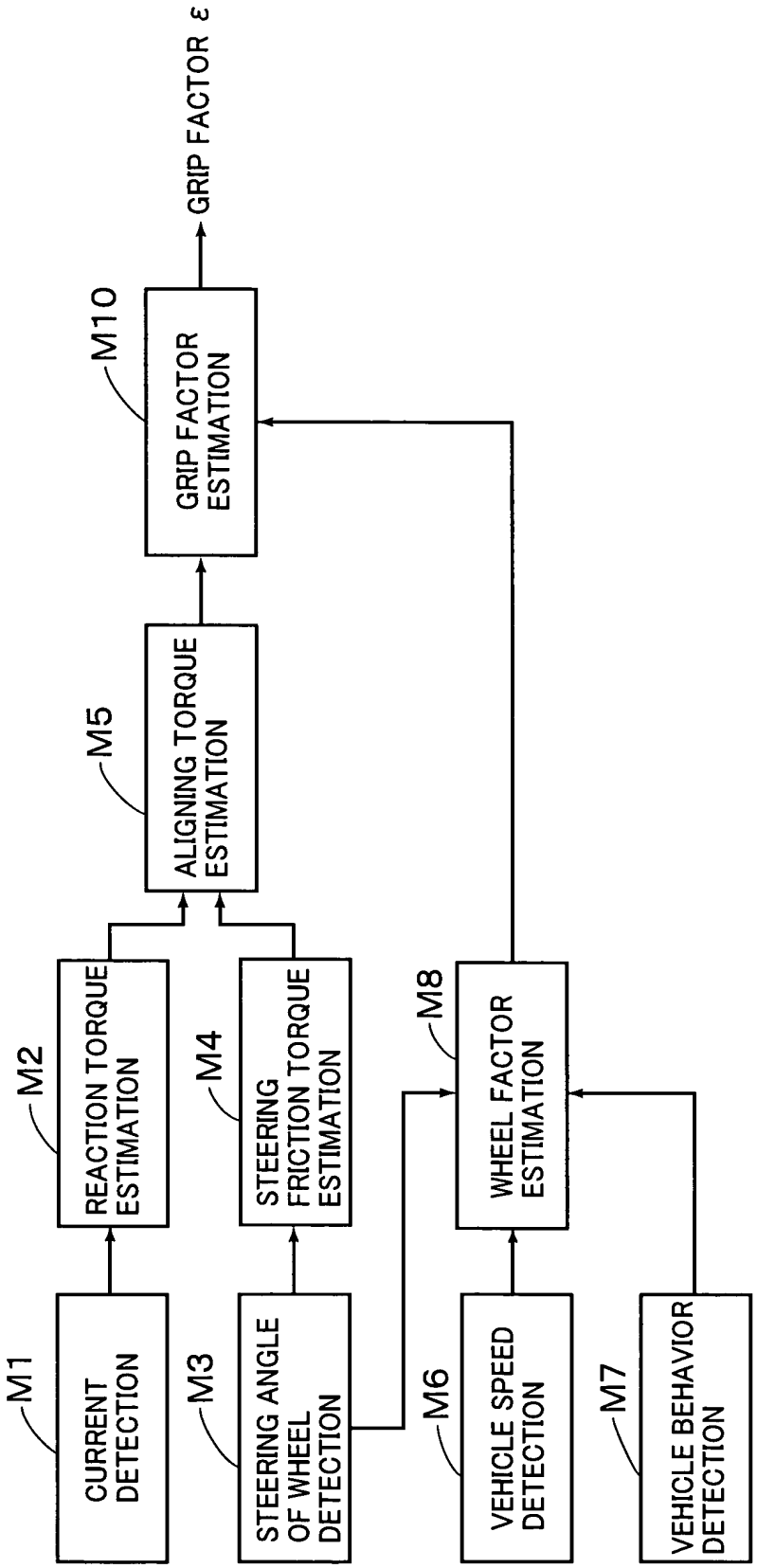

GRIP FACTOR ε
M10
GRIP FACTOR ESTIMATION
M5
ALIGNING TORQUE ESTIMATION
M2
REACTION TORQUE ESTIMATION
M4
STEERING FRICTION TORQUE ESTIMATION
M8
WHEEL FACTOR ESTIMATION
M1
CURRENT DETECTION
M3
STEERING ANGLE OF WHEEL DETECTION
M6
VEHICLE SPEED DETECTION
M7
VEHICLE BEHAVIOR DETECTION

FIG. 8

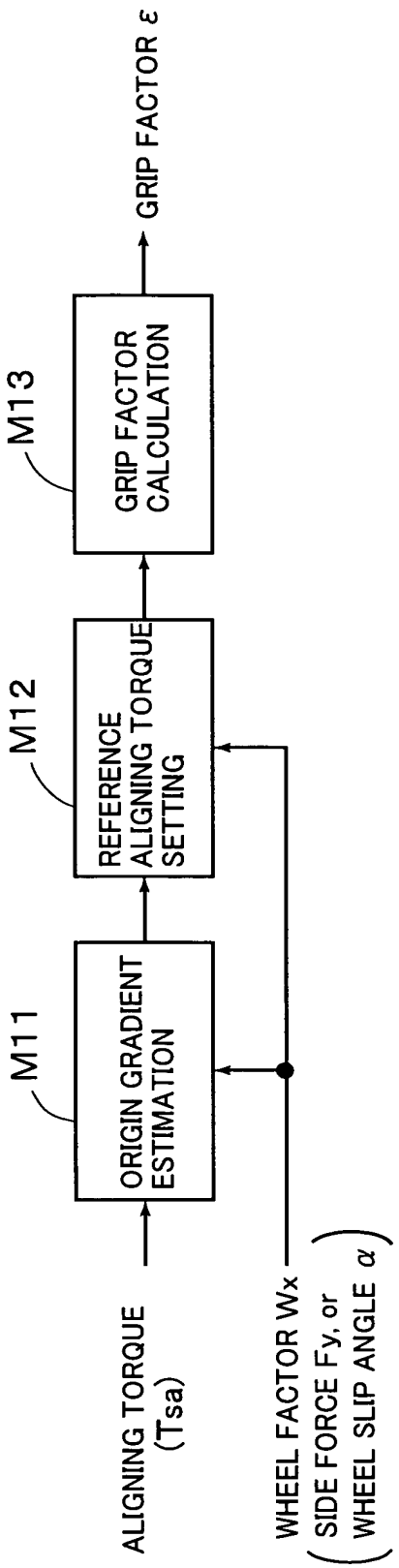

M11
ORIGIN GRADIENT ESTIMATION
M12
REFERENCE ALIGNING TORQUE SETTING
M13
GRIP FACTOR CALCULATION
GRIP FACTOR ε
ALIGNING TORQUE (Tsa)
WHEEL FACTOR Wx
(SIDE FORCE Fy, or
WHEEL SLIP ANGLE α)

FIG. 9

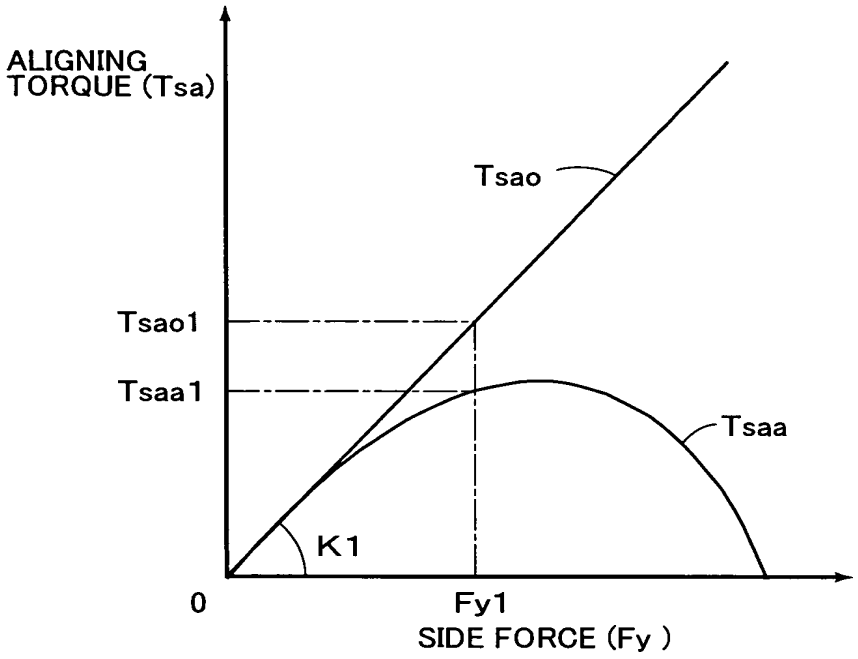

ALIGNING
TORQUE (Tsa)
Tsao
Tsao1
Tsaa1
Tsaa
K1
0
Fy1
SIDE FORCE (Fy)

FIG. 10

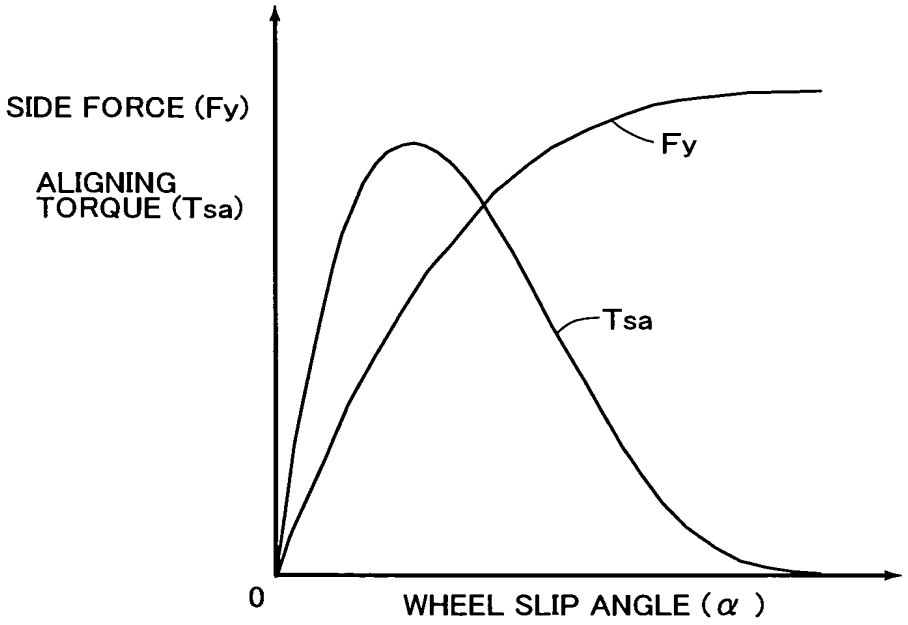

SIDE FORCE (Fy)
ALIGNING
TORQUE (Tsa)
Fy
Tsa
0
WHEEL SLIP ANGLE (α)

FIG. 11

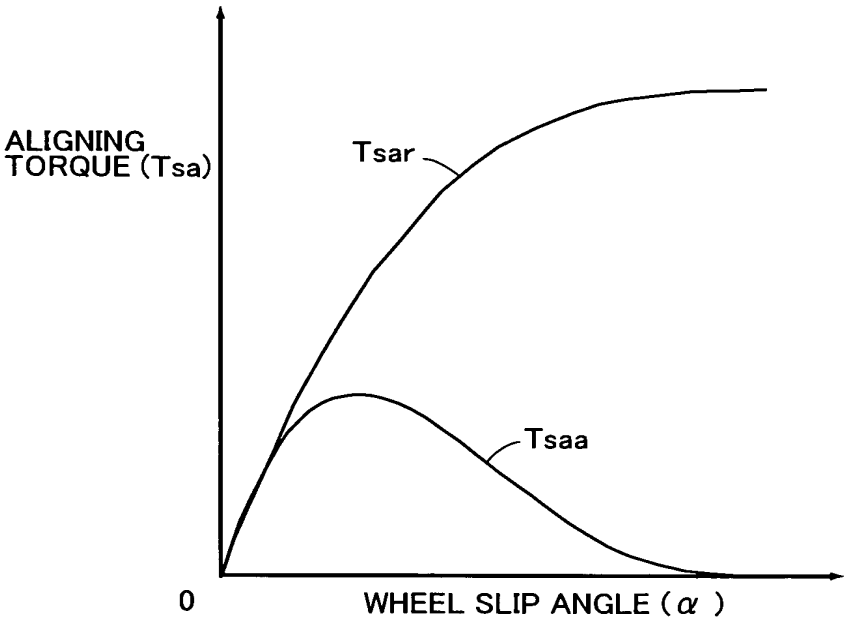

ALIGNING TORQUE (Tsa)
Tsar
Tsaa
0
WHEEL SLIP ANGLE (α)

FIG. 12

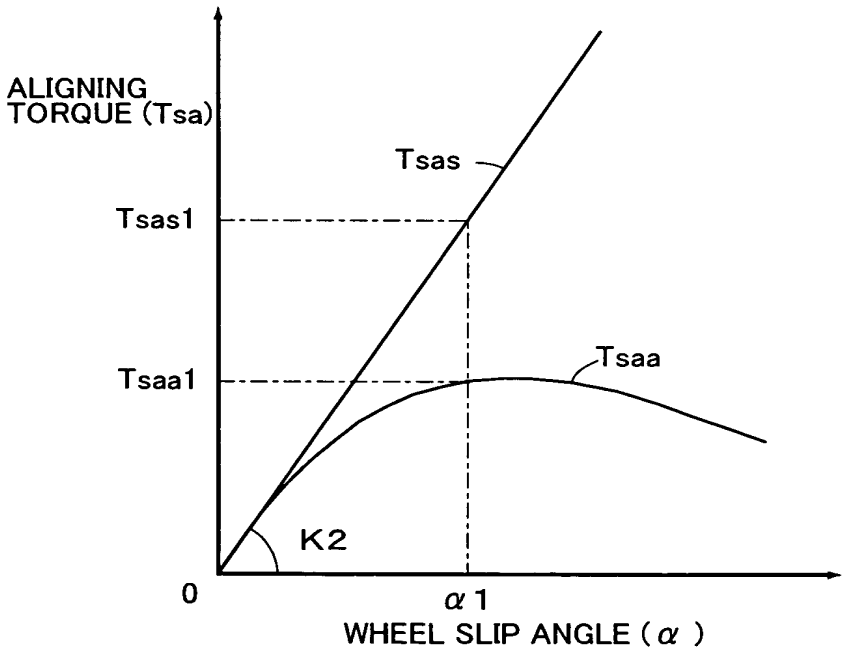

ALIGNING TORQUE (Tsa)
Tsas
Tsas1
Tsaa
Tsaa1
K2
0
α1
WHEEL SLIP ANGLE (α)

FIG. 13

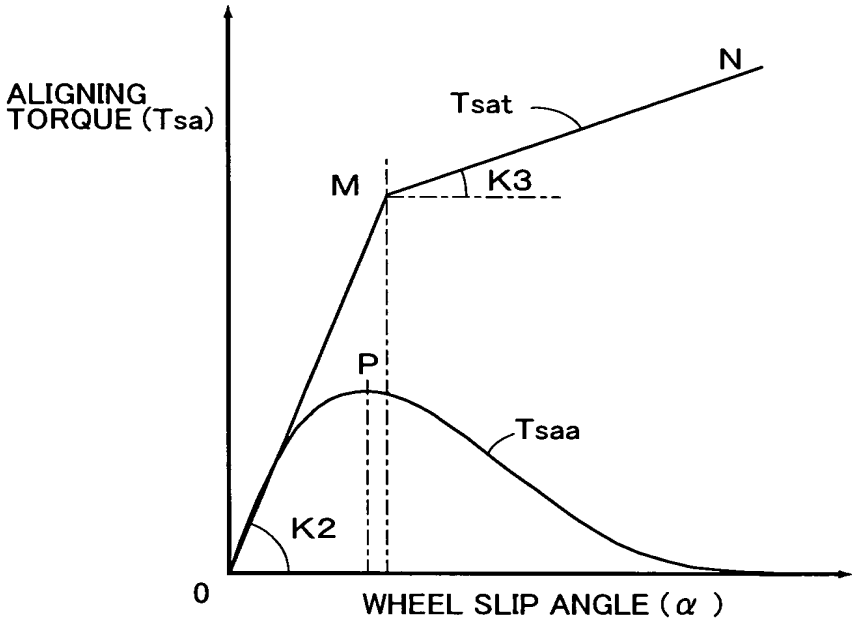

ALIGNING TORQUE (Tsa)
N
Tsat
M
K3
P
Tsaa
K2
0
WHEEL SLIP ANGLE (α)

FIG. 14

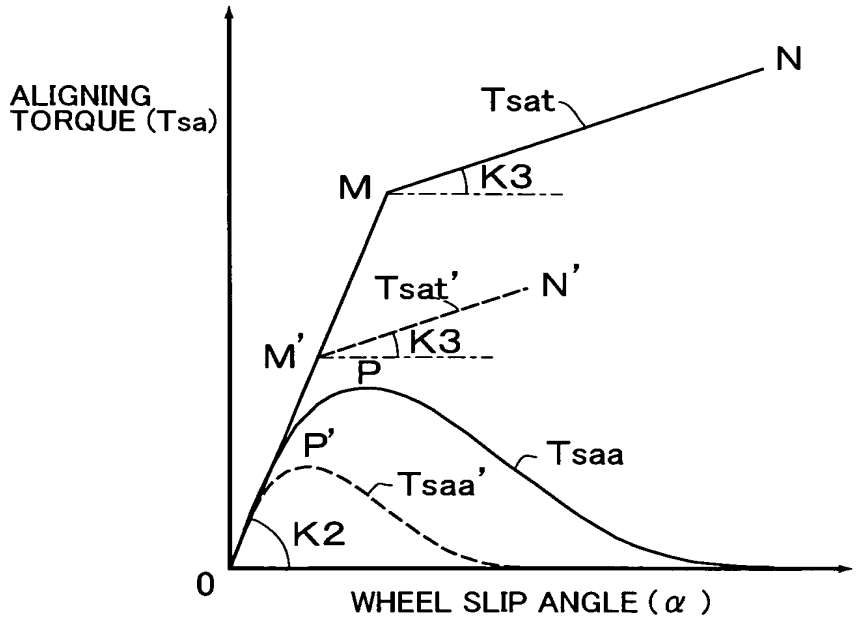

ALIGNING TORQUE (Tsa)
N
Tsat
M
K3
Tsat'
N'
M'
K3
P
P'
Tsaa
Tsaa'
K2
0
WHEEL SLIP ANGLE (α)

FIG. 15

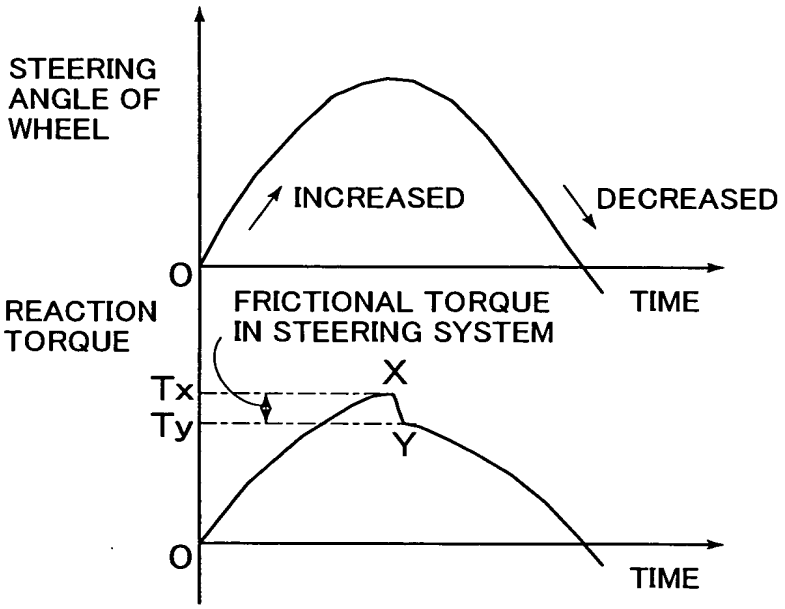

STEERING ANGLE OF WHEEL
INCREASED
DECREASED
O
TIME
REACTION TORQUE
FRICTIONAL TORQUE IN STEERING SYSTEM
X
Tx
Ty
Y
O
TIME

FIG. 16

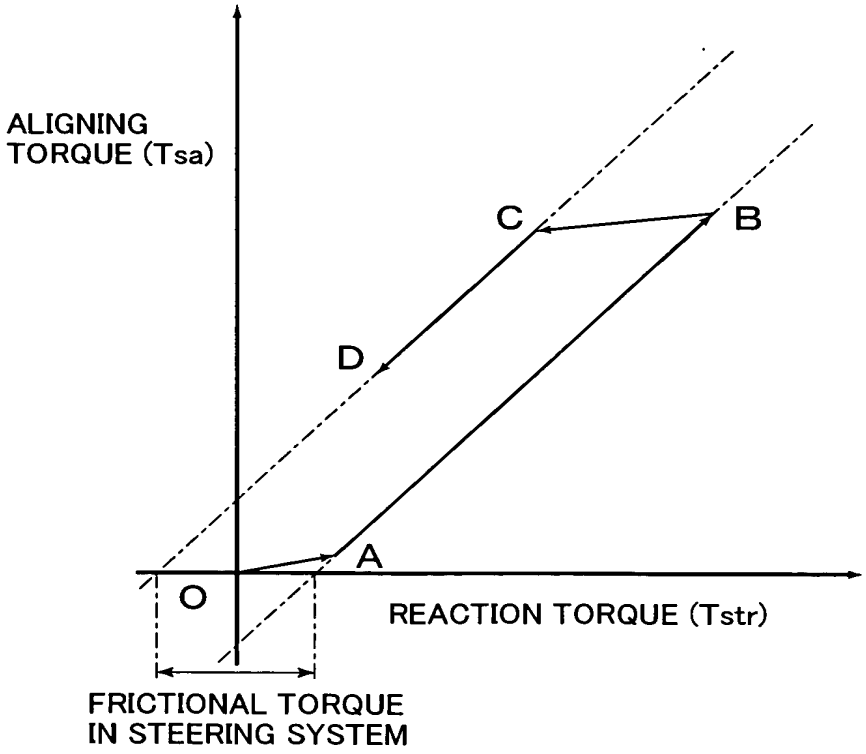

ALIGNING TORQUE (Tsa)
C
B
D
A
O
REACTION TORQUE (Tstr)
FRICTIONAL TORQUE IN STEERING SYSTEM

FIG. 17

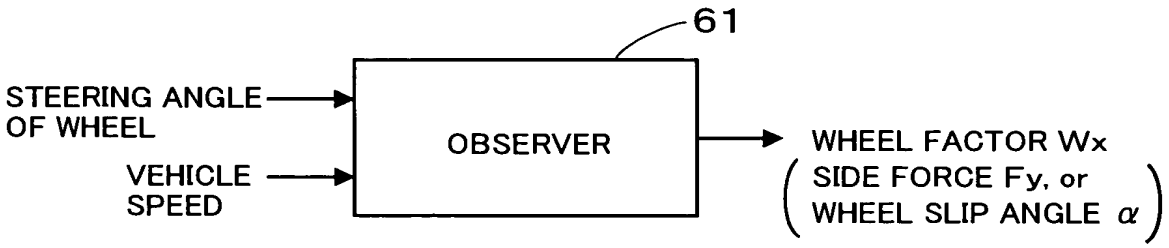


FIG. 18

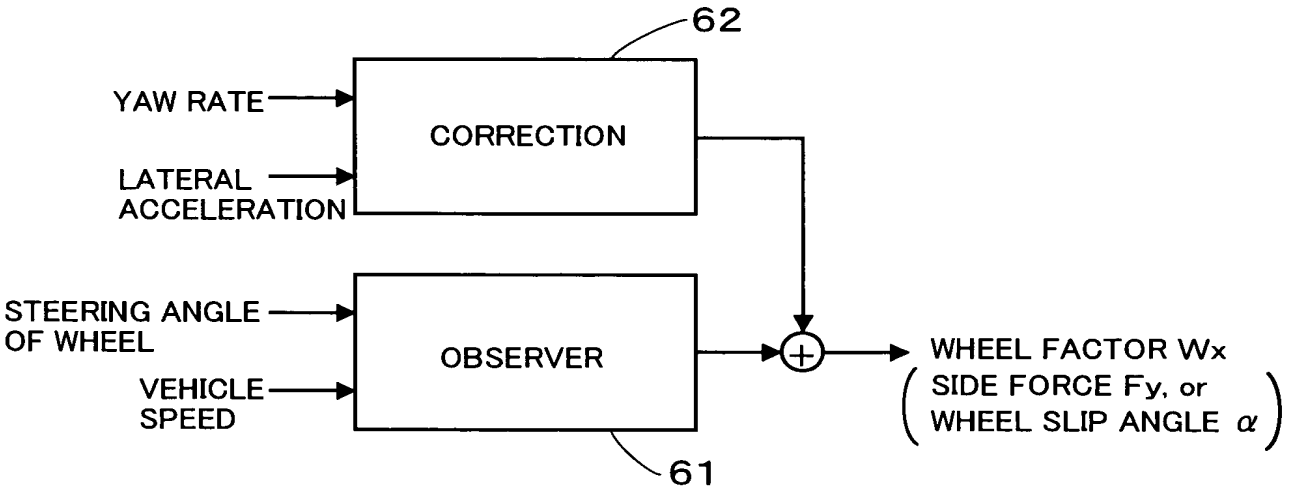


FIG. 19

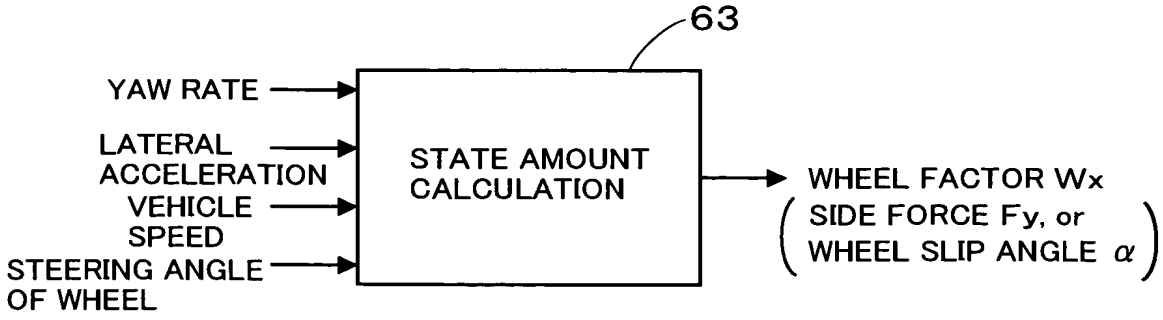


FIG. 20

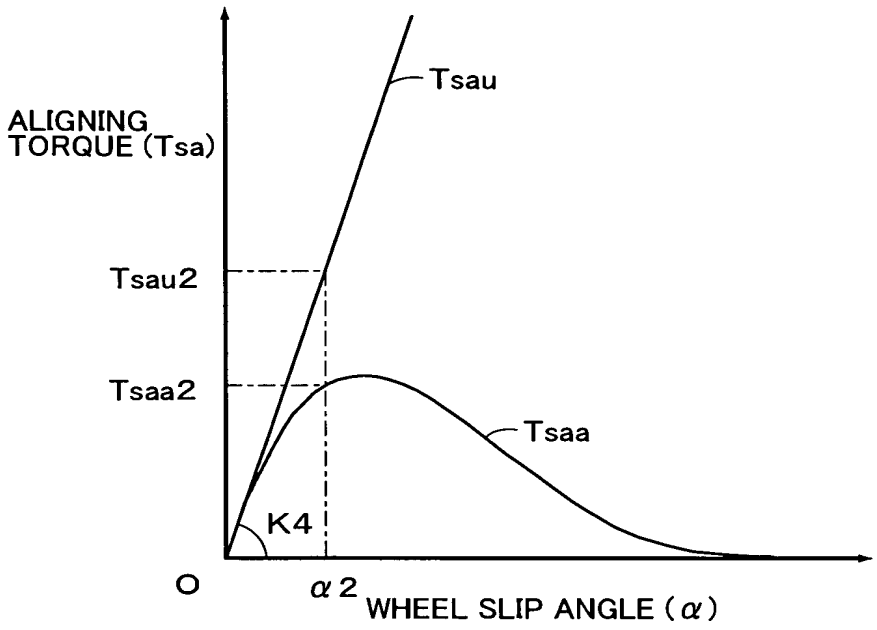

ALIGNING TORQUE (Tsa)
Tsau
Tsau2
Tsaa2
Tsaa
K4
O
α2
WHEEL SLIP ANGLE (α)

FIG. 21

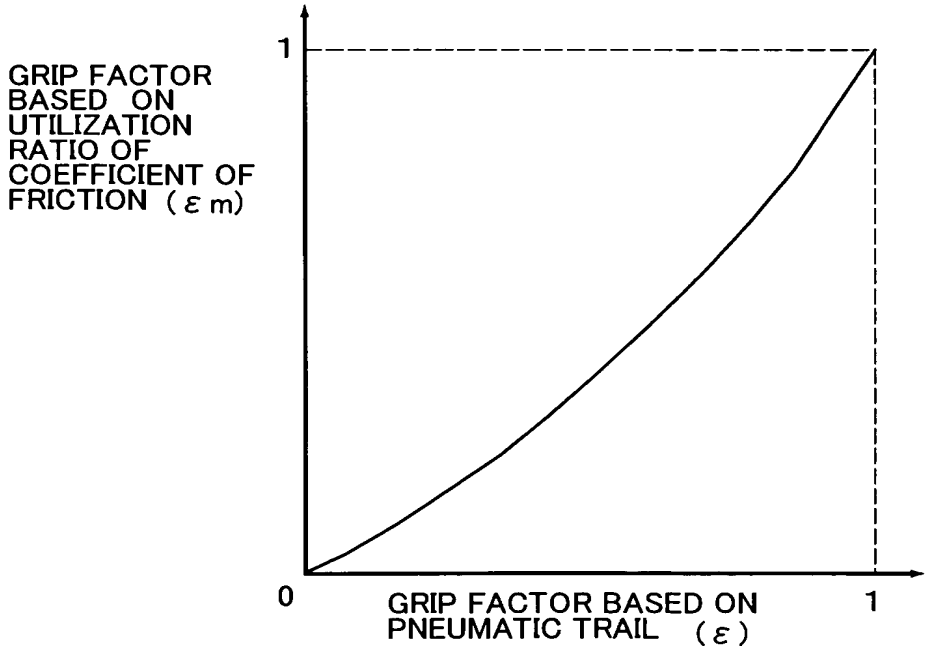

GRIP FACTOR BASED ON UTILIZATION RATIO OF COEFFICIENT OF FRICTION (εm)
1
0
GRIP FACTOR BASED ON PNEUMATIC TRAIL (ε)
1

FIG. 22

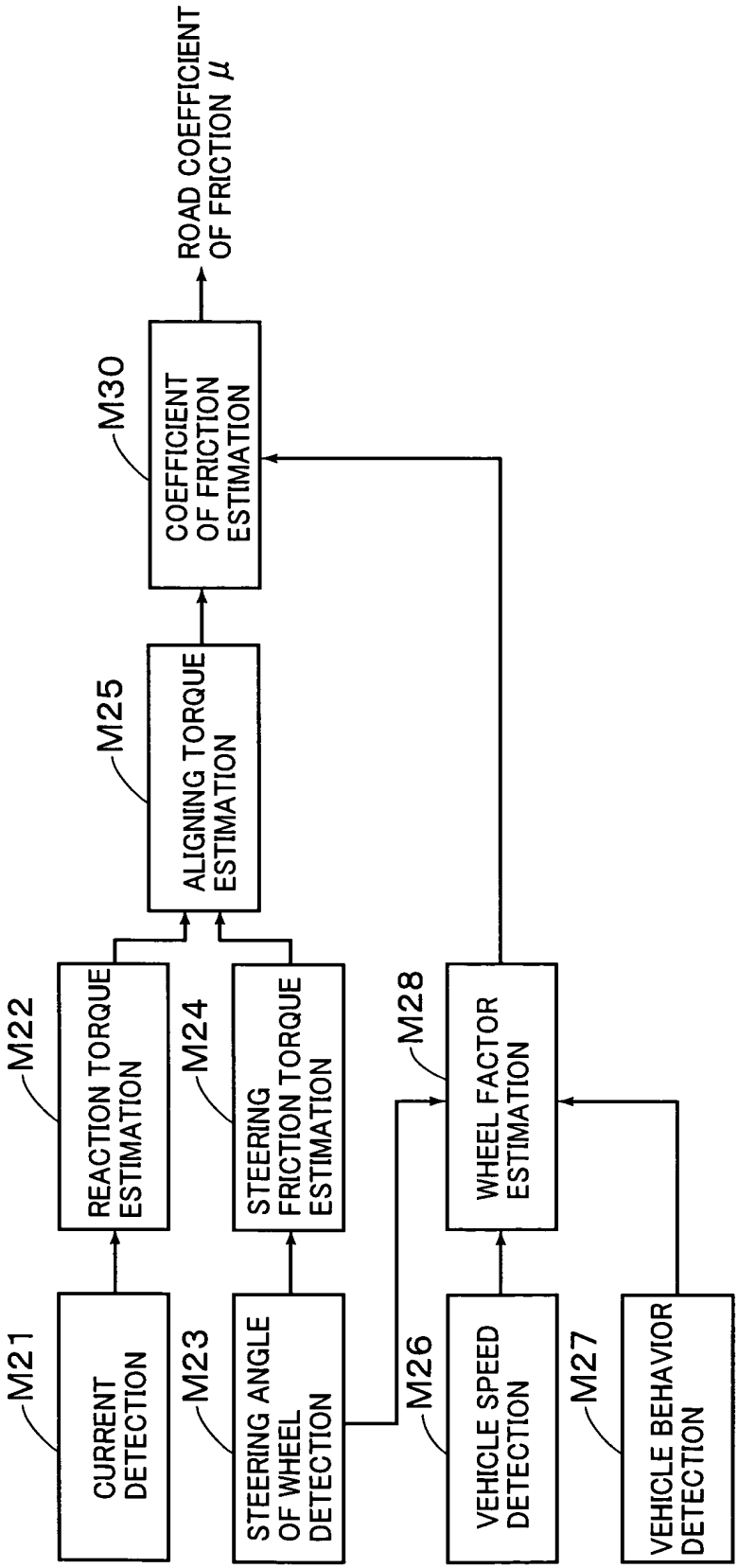

ROAD COEFFICIENT OF FRICTION μ
M30
COEFFICIENT OF FRICTION ESTIMATION
M25
ALIGNING TORQUE ESTIMATION
M22
REACTION TORQUE ESTIMATION
M24
STEERING FRICTION TORQUE ESTIMATION
M28
WHEEL FACTOR ESTIMATION
M21
CURRENT DETECTION
M23
STEERING ANGLE OF WHEEL DETECTION
M26
VEHICLE SPEED DETECTION
M27
VEHICLE BEHAVIOR DETECTION

FIG. 23

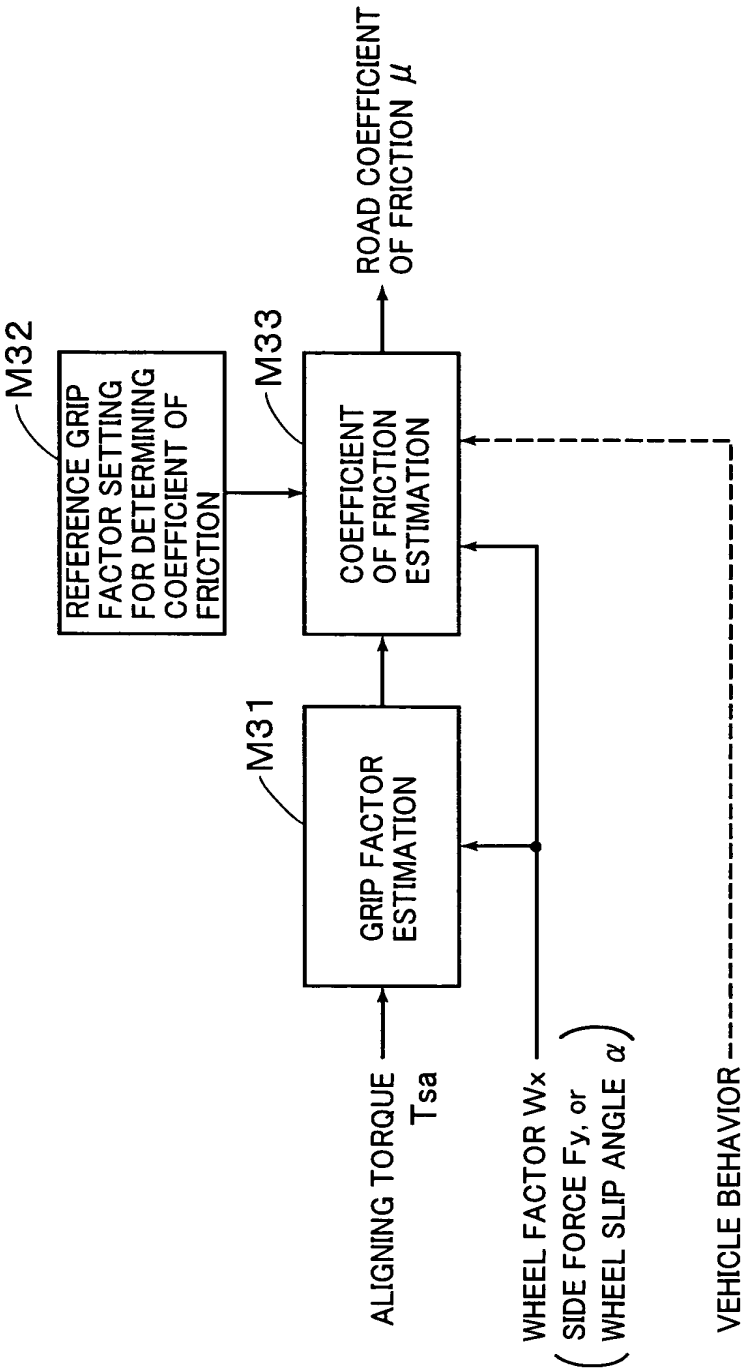

M32
REFERENCE GRIP FACTOR SETTING FOR DETERMINING COEFFICIENT OF FRICTION
M33
COEFFICIENT OF FRICTION ESTIMATION
ROAD COEFFICIENT OF FRICTION μ
M31
GRIP FACTOR ESTIMATION
ALIGNING TORQUE Tsa
WHEEL FACTOR Wx
(SIDE FORCE Fy, or WHEEL SLIP ANGLE α)
VEHICLE BEHAVIOR

FIG. 24

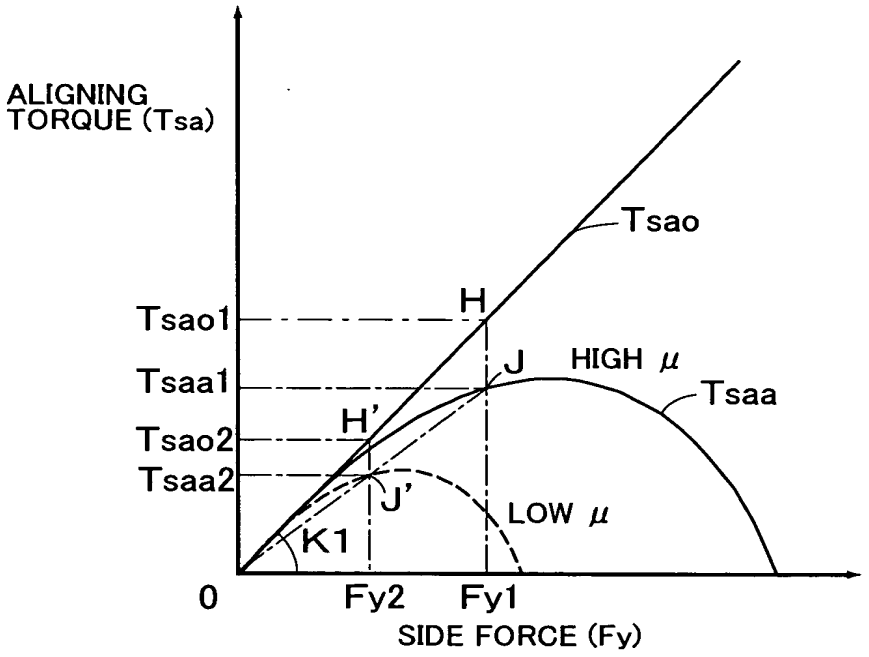

ALIGNING TORQUE (Tsa)
Tsao
H
Tsao1
J
HIGH μ
Tsaa1
Tsaa
H'
Tsao2
Tsaa2
J'
LOW μ
K1
0
Fy2
Fy1
SIDE FORCE (Fy)

FIG. 25

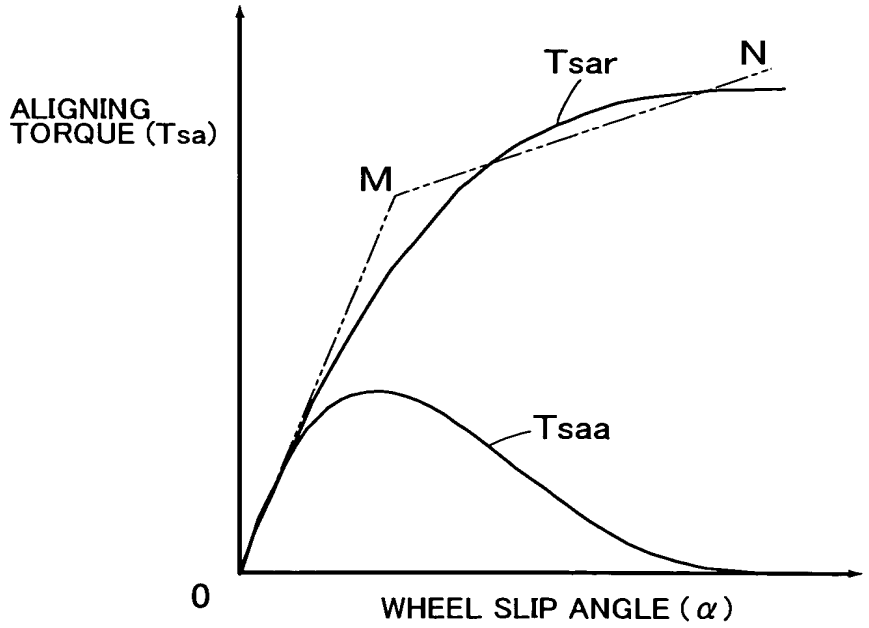

ALIGNING TORQUE (Tsa)
Tsar
N
M
Tsaa
0
WHEEL SLIP ANGLE (α)

FIG. 26

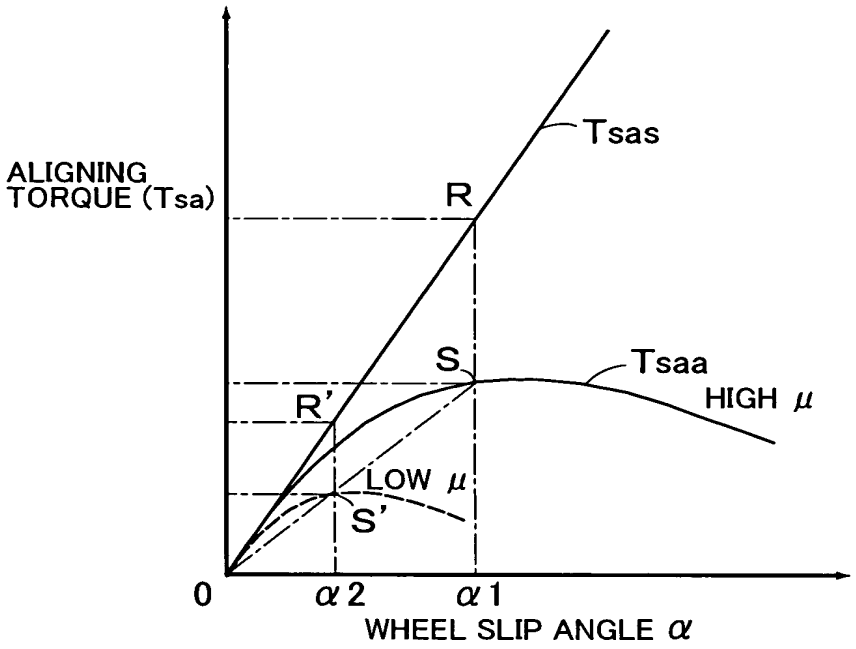

ALIGNING TORQUE (Tsa)
Tsas
R
S
Tsaa
HIGH μ
R'
LOW μ
S'
0
α2
α1
WHEEL SLIP ANGLE α

FIG. 27

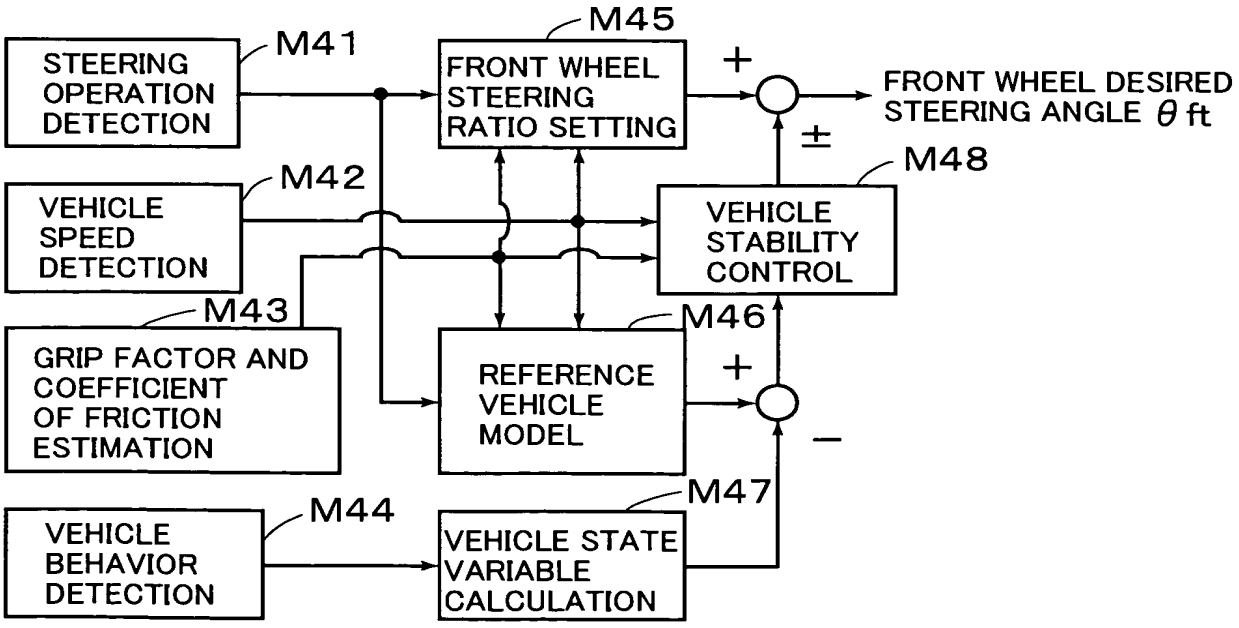

M41
STEERING OPERATION DETECTION
M42
VEHICLE SPEED DETECTION
M43
GRIP FACTOR AND COEFFICIENT OF FRICTION ESTIMATION
M44
VEHICLE BEHAVIOR DETECTION
M45
FRONT WHEEL STEERING RATIO SETTING
M46
REFERENCE VEHICLE MODEL
M47
VEHICLE STATE VARIABLE CALCULATION
M48
VEHICLE STABILITY CONTROL
+
±
+
−
FRONT WHEEL DESIRED STEERING ANGLE θft

FIG. 28

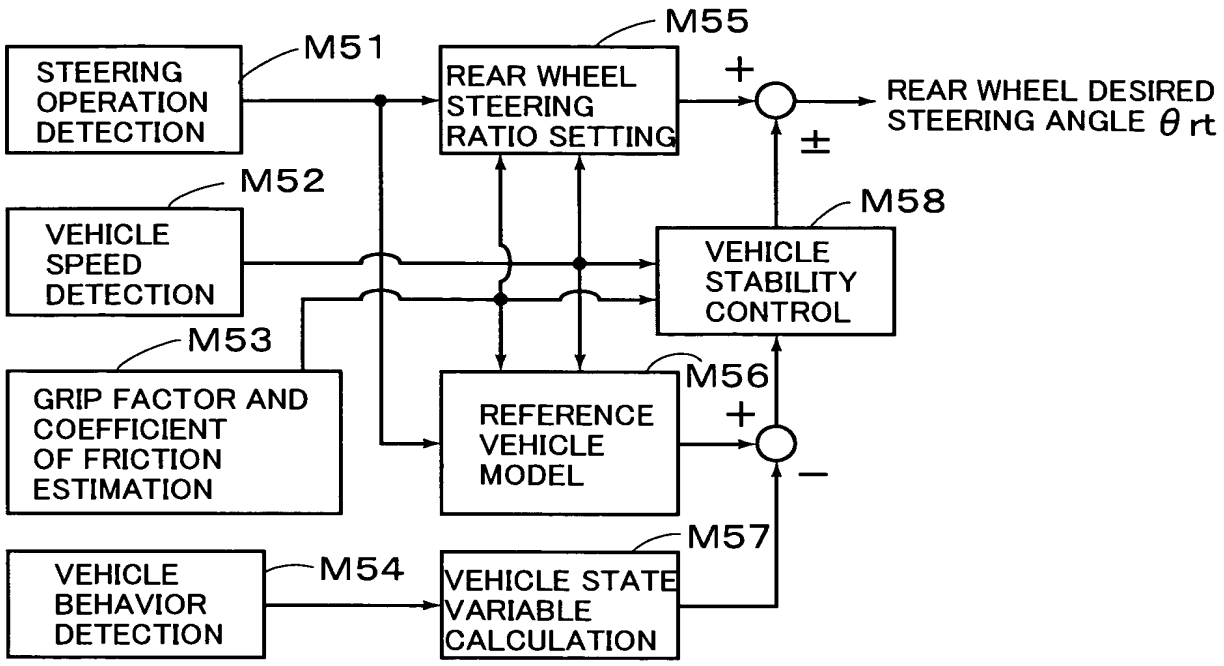

M51
STEERING OPERATION DETECTION
M52
VEHICLE SPEED DETECTION
M53
GRIP FACTOR AND COEFFICIENT OF FRICTION ESTIMATION
M54
VEHICLE BEHAVIOR DETECTION
M55
REAR WHEEL STEERING RATIO SETTING
M56
REFERENCE VEHICLE MODEL
M57
VEHICLE STATE VARIABLE CALCULATION
M58
VEHICLE STABILITY CONTROL
+
±
+
−
REAR WHEEL DESIRED STEERING ANGLE θrt

FIG. 29

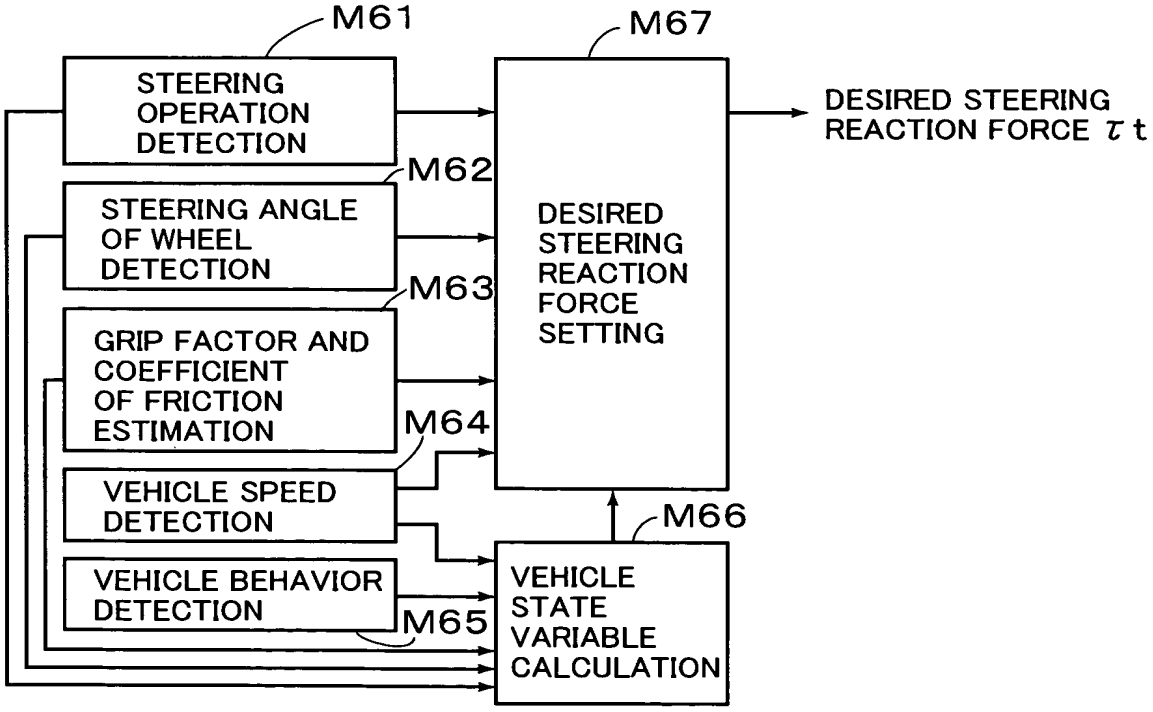

M61
STEERING OPERATION DETECTION
M62
STEERING ANGLE OF WHEEL DETECTION
M63
GRIP FACTOR AND COEFFICIENT OF FRICTION ESTIMATION
M64
VEHICLE SPEED DETECTION
M65
VEHICLE BEHAVIOR DETECTION
M67
DESIRED STEERING REACTION FORCE SETTING
M66
VEHICLE STATE VARIABLE CALCULATION
DESIRED STEERING REACTION FORCE τt

FIG. 30

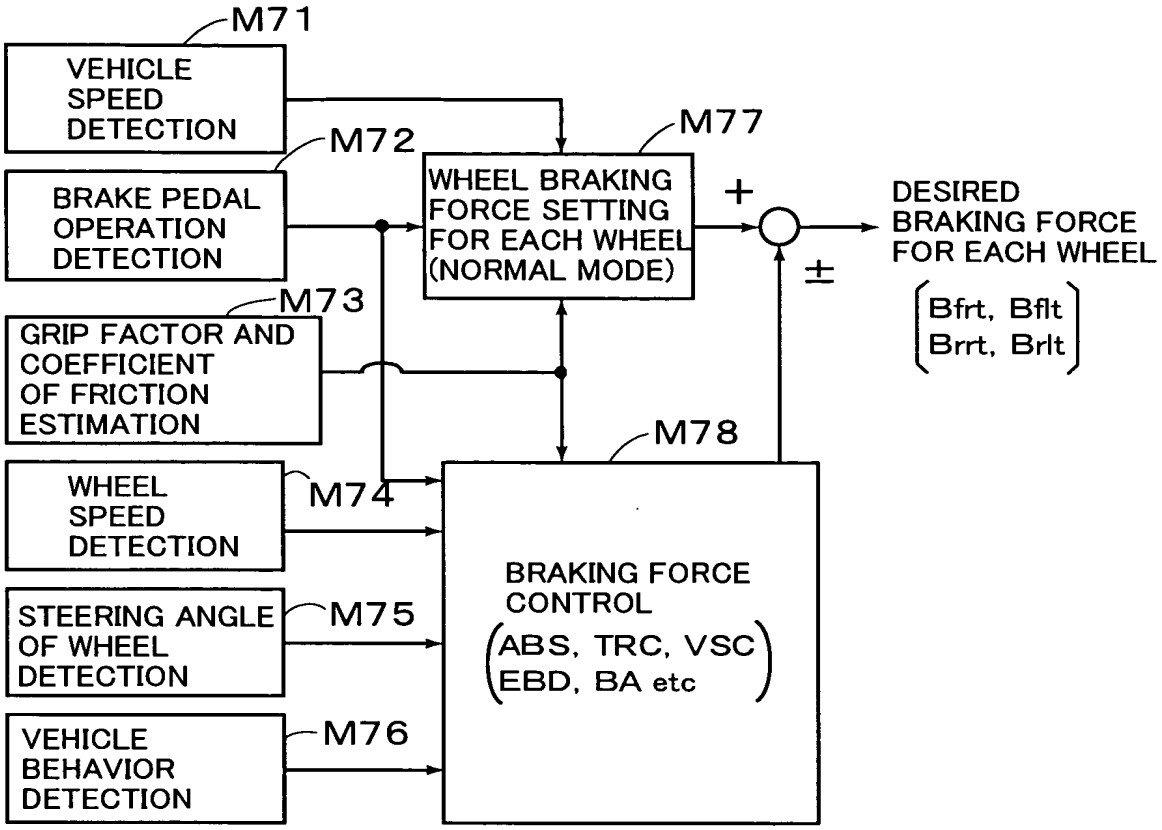
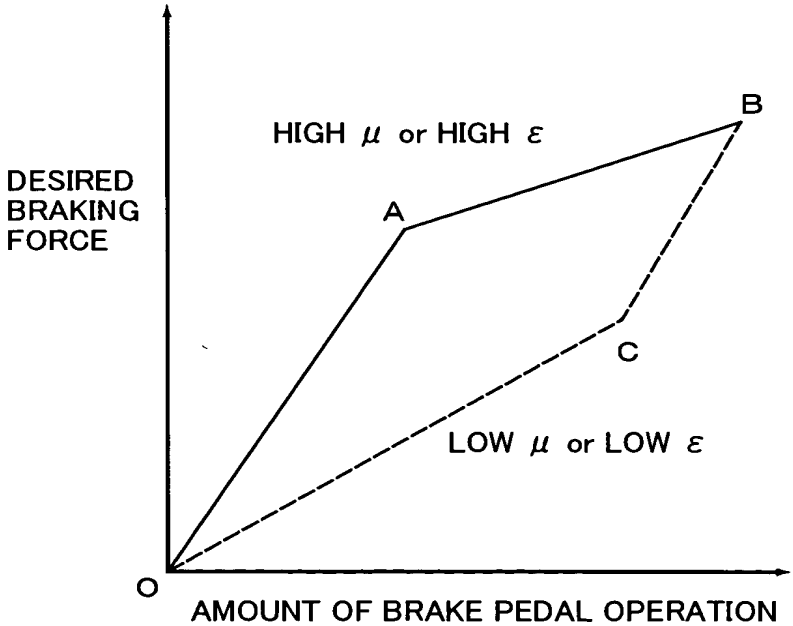

M71
VEHICLE SPEED DETECTION
M72
BRAKE PEDAL OPERATION DETECTION
M73
GRIP FACTOR AND COEFFICIENT OF FRICTION ESTIMATION
M74
WHEEL SPEED DETECTION
M75
STEERING ANGLE OF WHEEL DETECTION
M76
VEHICLE BEHAVIOR DETECTION
M77
WHEEL BRAKING FORCE SETTING FOR EACH WHEEL (NORMAL MODE)
+
±
DESIRED BRAKING FORCE FOR EACH WHEEL
(Bfrt, Bflt
Brrt, Brlt)
M78
BRAKING FORCE CONTROL
(ABS, TRC, VSC
EBD, BA etc)

FIG. 31


DESIRED BRAKING FORCE
HIGH μ or HIGH ε
B
A
C
LOW μ or LOW ε
O
AMOUNT OF BRAKE PEDAL OPERATION